Pestic. Sci. 1997, **51**, 371–374

Resistance of *Phytophthora porri* to Metalaxyl*

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(Received 1 May 1997; revised version received 1 July 1997; accepted 15 July 1997)

Abstract: Metalaxyl resistance has been identified in the *Phytophthora porri* population in the UK. In field experiments the presence of such resistant strains reduced the level of control of leek white tip given by applications of phenylamide-containing fungicides. The level of control achieved by fungicides with alternative modes of action to the phenylamides was not affected.

Pestic Sci., **51**, 371–374, 1997
No. of Figures: 0. No. of Tables: 3. No. of Refs: 14

Key words: phenylamide, metalaxyl, oxadixyl, leek white tip, *Phytophthora porri*

1 INTRODUCTION

White tip, caused by the soil-borne fungal pathogen *Phytophthora porri* Foister can be a devastating disease of leeks (*Allium porrum* L.). The disease has been recognised in the United Kingdom for many years and *P. porri* was identified as the cause in 1931.[1] The pathogen was later confirmed as attacking onions[2,3] and causing a storage rot of cabbage.[4] Infection of leeks occurs during wet weather and large areas of leaf tissue may become bleached and desiccated. Yield reductions due to white tip are mainly due to the removal of infected leaves prior to marketing. However, severe infections may halt plant growth and the whole plant can become unsaleable. In the 1970s and 1980s suppression of white tip was achieved by routine fungicide spray programmes of captafol. Some control was also given by the dithiocarbamate complex of ferbam, maneb and zineb. By 1988 captafol had been withdrawn from the market and approval for use on leeks was given for the phenylamide fungicide metalaxyl, for which a formulation incorporating mancozeb was available. Later, a formulation of metalaxyl and chlorothalonil was recommended for white tip control. These mixtures were found to be as effective as captafol in the control of white tip and, in some experiments, significantly better (Table 1).[5] In trials, some fungicide treatments have increased marketable yield by nearly 80%.[5]

Leek growers readily adopted metalaxyl-containing products for white tip control, but by the mid-1990s some concern was being expressed about the efficacy of these fungicides. Pathogen resistance to phenylamide fungicides has been reported in the UK in the case of *Phytophthora infestans* (Mont.) DeBary,[6] *Peronospora parasitica* Fr.,[7] *Bremia lactucae* Regel[8] and *Pythium* spp.[9] Elsewhere resistance to this group of fungicides has occurred in *Phytophthora erythroseptica* Pethyb.,[9] *Plasmopara viticola* Berl. & De Toni,[10] *Peronospora tabacina* Adam[11] and *Pseudoperonospora humuli* (Miyabe & Takah) Wilson.[12,13] There was, therefore, some suspicion that the poor level of *P. porri* control occasionally observed following the use of metalaxyl might be due to the presence of phenylamide-resistant strains of the pathogen. A study was undertaken to discover if such resistance existed and to evaluate what alternative fungicides might be used for white tip control.

2 MATERIALS AND METHODS

2.1 Field experiments

Fully randomised experiments were carried out at two sites, Burscough (Lancashire) and Wargrave (Berkshire), during 1995/96 where fungicides were evaluated for

* Based on a presentation at the Conference 'Resistance '97—Integrated Approach to Combating Resistance' organised by the Institute of Arable Crops Research in collaboration with the SCI Pesticides Group and the British Crop Protection Council and held at Harpenden, Herts, UK on 14–16 April 1997.
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Contract grant sponsor: Horticultural Development Council.

TABLE 1
Effect of Fungicides on White Tip Infection 1987/88[a]

Treatment	*Mean leaf area affected by white tip* (%)[b]		*Mean reduction in white tip infection* (%)	
	Wallasey	*Pershore*	*Wallasey*	*Pershore*
Untreated	23·7 c	4·0 d	—	—
Captafol	17·0 b	1·7 ab	28·2	57·5
Ferbam + maneb + zineb	17·5 b	2·9 c	26·2	27·5
Chlorothalonil	17·8 b	2·6 bc	24·9	35·0
Metalaxyl + mancozeb	10·8 a	1·3 a	54·4	67·5
Metalaxyl + chlorothalonil	11·0 a	1·5 a	53·6	62·5

[a] Data from Reference 5.
[b] Duncan's multiple range analysis: Figures followed by a common letter in a column are not significantly different at ($P \leqq 0{\cdot}05$). Statistical significance of percentages based on angle-transformed data.

white tip control. The crops used were direct drilled leek cv. Rami (Burscough) and transplanted leek cv. Farinto (Wargrave) established in April and July 1995, respectively. Each experimental treatment was replicated four times and plots were three rows wide by 20 m (Burscough) or 10 m (Wargrave) in length. Fungicides were applied by knapsack sprayer in water at a rate equivalent to 300 litre ha^{-1} on 21 September, 11 October, 31 October, 29 November 1995 and 1 March 1996 at Burscough and on 11 October, 1 November, 22 November 1995 and 13 March at Wargrave.

2.2 Fungicide treatments

Twelve fungicides known to have activity against *Phytophthora* spp. were tested in the experiments. These included seven which are reported upon in this paper: metalaxyl + chlorothalonil ('Folio' 575 SC, Ciba Agriculture), cymoxanil + mancozeb + oxadixyl ('Trustan' WDG, DuPont (UK) Ltd), fluazinam ('Shirlan', Zeneca Crop Protection), dimethomorph + mancozeb ('Invader', Cyanamid of Great Britain Ltd), propamocarb hydrochloride + mancozeb ('Tattoo', AgrEvo UK Crop Protection Ltd), propamocarb hydrochloride ('Fisons Filex', Levington Horticulture Ltd), and cymoxanil + mancozeb ('Curzate' M, Dupont (UK) Ltd). Details of products and rates of use are given in Table 2. All products were applied at the manufacturer's recommended rate on leeks, or at a rate suggested by the manufacturer if the product had no label recommendation for that crop.

2.3 Disease assessments

White tip infection levels were monitored at intervals from October 1995 onwards, with the final assessments

TABLE 2
Fungicide Active Ingredients, Concentrations and Rates of Use in Leek Experiments 1995/96

Active ingredients	*Content* (*g litre*$^{-1}$/***g kg***$^{-1}$)	*Rate of use* (*litre ha*$^{-1}$/***kg ha***$^{-1}$)
Metalaxyl +	75	
chlorothalonil	500	2·0
Cymoxanil +	**32**	
oxadixyl +	**80**	
mancozeb	**560**	**2·5**
Dimethomorph +	**75**	
mancozeb	**667**	**2·0**
Fluazinam	500	0·3
Propamocarb hydrochloride +	248	
mancozeb	302	4·0
Cymoxanil +	**45**	
mancozeb	**680**	**2·0**
Propamocarb hydrochloride	722	1·5

taking place in March 1996. The percentage leaf area affected by white tip was recorded for 10 plants per plot and a mean level of infection calculated.

2.4 Fungicide resistance screening

In March 1996 samples of white-tip-infected leaves were taken from the untreated and metalaxyl + chlorothalonil treated plots at both sites. *P. porri* was isolated on to $P_{100}VP$ agar[14] and then subcultured on to unamended potato dextrose agar (PDA) or PDA amended with 2 or 20 $\mu g\ ml^{-1}$ metalaxyl. Isolates which grew on the amended agar were further screened on agar amended with 20, 50, 200 and 500 $\mu g\ ml^{-1}$ metalaxyl. Radial mycelial growth was measured after four days and the ED_{50} value of each isolate was calculated.

3 RESULTS

3.1 Field experiments

White tip disease progress was slow during the autumn of 1995 at both sites, but new infections occurred in February and March 1996. By the time of the final assessments, (in March) 23·8% of the leaf area of the untreated plants was affected at Wargrave and 7·5% at Burscough. All fungicide treatments reduced disease levels significantly at Wargrave and the majority did so at Burscough (Table 3).

3.2 Fungicide resistance screening

Nineteen isolates of *P. porri* were obtained from leaf material taken from the Burscough experiment. Due to extensive sooty mould contamination of the leaf material at Wargrave, only seven isolates of *P. porri* were cultured successfully.

All *P. porri* isolates obtained from both the untreated and metalaxyl + chlorothalonil treated plots in the Burscough experiment grew on agar amended with 2 or 20 $\mu g\ ml^{-1}$ metalaxyl. One of the Wargrave isolates grew similarly, whilst complete inhibition of growth occurred at 2 $\mu g\ ml^{-1}$ metalaxyl with all other six isolates. Isolates making growth on the amended agar were considered metalaxyl-resistant, and those inhibited at 2 $\mu g\ ml^{-1}$ were considered metalaxyl-sensitive. The mean ED_{50} value of the metalaxyl-resistant isolates was 30 $\mu g\ ml^{-1}$. These results suggest that at Wargrave approximately 14% (=one isolate) of the *P. porri* population was resistant to phenylamide fungicides, but at Burscough the whole population was resistant.

4 DISCUSSION

The existence of metalaxyl-resistant strains of the leek white tip pathogen *P. porri* has been demonstrated. At the Burscough site all of the *P. porri* isolates screened were resistant, whilst at the Wargrave site 14% were resistant. In the field experiments, the performance of the two fungicides containing the phenylamides metalaxyl and oxadixyl was worse at the site where metalaxyl resistance was the norm. The level of control given by the phenylamide-containing products at the Wargrave site was consistent with that previously reported in 1987/88.[5] Overall, disease control was slightly lower at Burscough than at Wargrave. Allowing for this, the performance of those products not dependent upon phenylamide fungicides was similar at the two sites, being on average 12% lower at Burscough. In comparison, the level of control given by the two phenylamide-containing products was 43–46% lower at that site.

TABLE 3
Effect of Fungicides on White Tip Infection 1995/96

	Mean leaf area affected by white tip (%)[a]		*Mean reduction in white tip infection* (%)	
Treatment	*Wargrave*	*Burscough*	*Wargrave*	*Burscough*
Untreated	23·78 d	7·48 c	—	—
Metalaxyl + chlorothalonil	9·80 ab	4·95 ab	58·8	33·8
Cymoxanil + oxadixyl + mancozeb	8·13 a	4·82 ab	65·8	35·6
Dimethomorph + mancozeb	8·55 a	3·13 a	64·0	58·2
Fluazinam	9·60 ab	3·25 a	59·6	56·6
Propamocarb hydrochloride + mancozeb	9·20 ab	3·15 a	61·3	57·9
Cymoxanil + mancozeb	9·55 ab	4·20 ab	59·8	43·9
Propamocarb hydrochloride	11·07 abc	4·10 ab	53·4	45·2
SE	1·269	0·583		
df	50	54		

[a] Duncan's multiple range analysis: Figures followed by a common letter in a column are not significantly different at $P \leq 0{\cdot}05$. (Analysis refers to that performed on the whole of the experimental data.)

Complete loss of control by these two products where *P. porri* was phenylamide-resistant would not be expected as the mixtures both contain active ingredients with alternative modes of action, so would still have some activity.

This study has shown that, where phenylamide-resistant strains are common in the *P. porri* population attacking a leek crop, the efficacy of products containing phenylamide fungicides was considerably reduced. Studies are in progress to determine the extent of *P. porri* phenylamide resistance in leek crops in England and Wales. Furthermore, metalaxyl has recently been recommended for use as a pre-storage dip treatment to prevent *P. porri* infection of cabbage. The existence of resistant strains may limit the value of this treatment.

ACKNOWLEDGEMENTS

The authors wish to thank the Leek Growers Association for drawing their attention to the developing problem of white tip control. The work described here was funded by the Horticultural Development Council, and further information can be obtained in the report of Project FV 172.

REFERENCES

1. Foister, C. E., The white tip disease of leeks and its causal fungus, *Phytophthora porri n.sp. Trans. Proc. Bot. Soc. Edinburgh*, **30** (1931) 257–81.
2. Tichelaar, G. M. & van Kesteren, H. A., Aantasting van Ui door *Phytophthora porri. Neth. J. Pl. Path.*, **73** (1976) 103–4.
3. Griffin, M. J. & Jones, O. W., *Phytophthora porri* on autumn-sown salad onions. *Pl. Path.*, **26** (1977) 149–50.
4. Geeson, J. D., Storage rot of white cabbage caused by *Phytophthora porri. Pl. Path.*, **25** (1976) 115–16.
5. Dobson, S. C. & Clarkson, J. D. S., Comparison of fungicides for the control of white tip (*Phytophthora porri*) on leeks. *Test of Agrochemicals and Cultivars 10. Ann. Appl. Biol.*, **114** (Supplement) (1989) 42–3.
6. Davidse, L. C., Looijen, D., Turkensteen, L. J. & Van der Wal, D., Occurrence of metalaxyl-resistant strains of *Phytophthora infestans* in Dutch potato fields. *Neth. J. Pl. Path.*, **87** (1981) 65–8.
7. Crute, I. R., Norwood, J. M. & Gordon, P. L., Resistance to phenylamide fungicides in lettuce and brassica downy mildew. *Fungicides for Crop Protection: 100 years of Progress. BCPC Monograph No 31* (1985) 311–14.
8. White, J. G., Dobson, S. C. & Tulip, J. R., Resistance to furalaxyl in *Pythium* spp. isolated from bedding plants and compost. *Tests on Agrochemicals and Cultivars 10, Ann. Appl. Biol.*, **114** (Supplement) (1989) 176–7.
9. Goodwin, S. B. & McGrath, M. T., Insensitivity to metalaxyl among isolates of *Phytophthora erythroseptica* causing pink rot of potato in New York. *Plant Dis.*, **79** (1995) 967.
10. Hertzog, J. & Schüepp, H., Three types of sensitivity to metalaxyl in *Plasmopora viticola. Phytopath. Z.*, **114** (1985) 90–3.
11. Todd, F., The blue mold situation in Central America and the Caribbean region. *Blue Mold Symposium* **111**. *30th Tobacco Workers Conference* (1983) 14–19.
12. Hellwig, K., Kremheller, H. T. & Agerer, R., Untersuchungen zur Resistenz von *Pseudoperonospora humuli* (Miy. & Tak.) Wilson gegenuber Metalaxyl. *Gesunde Pfanzen* **43** (1991) 400–4.
13. Klein, R. E. Occurrence and incidence of metalaxyl resistance in *Pseudoperonospora humuli* in the Pacific Northwest. *Pl. Disease*, **78** (1994) 161–3.
14. Tsao, P. H. & Ocana, G., Selective isolation of species of *Phytophthora* from natural soils on an improved antibiotic medium. *Nature* (*London*) **223** (1969) 636–8.